

2020-05-19

Conservation and Management Challenges Facing a Medicinal Plant *Zanthoxylum chalybeum* in Simanjiro Area, Northern Tanzania

Mbinile, Scholastica


MDPI

<https://doi.org/10.3390/su12104140>

Provided with love from The Nelson Mandela African Institution of Science and Technology

Article

Conservation and Management Challenges Facing a Medicinal Plant *Zanthoxylum chalybeum* in Simanjiro Area, Northern Tanzania

Scholastica D. Mbinile * , Linus K. Munishi, Issakwisa B. Ngondya and Patrick A. Ndakidemi

Department of Sustainable Agriculture, Biodiversity and Ecosystem Management, School of Life Sciences and Bioengineering, The Nelson Mandela African Institution of Science and Technology (NM-AIST), Arusha P.O. Box 447, Tanzania; linus.munishi@nm-aist.ac.tz (L.K.M.); issakwisa.ngondya@nm-aist.ac.tz (I.B.N.); patrick.ndakidemi@nm-aist.ac.tz (P.A.N.)

* Correspondence: mbiniles@nm-aist.ac.tz

Received: 22 February 2020; Accepted: 7 April 2020; Published: 19 May 2020



Abstract: The information on the medicinal use, availability, challenges, and future conservation strategies for the medicinal plant *Zanthoxylum chalybeum* were gathered by using a semi-structured questionnaire, focused group discussions, and field observations in Simanjiro Area, Tanzania. Data were collected from local village members who were familiar with the tree and the key informants. Data were analyzed using Statistical Package for the Social Sciences (SPSS). The extent of use was found to be very high, with more than three-quarters of harvested parts used for treating women's health system (86.4%). The most used plant parts for medicinal purposes were reported to be the roots and the stem bark (90.3% and 81.6%, respectively), possibly suggesting mortality caused by heavy harvesting. In addition to unsustainable harvesting methods, minimal and unpredictable propagation methods were the key factors affecting the recruitment rate, with perhaps an addition of continued climate and land-use change (93.2%), indicative of low precipitation and high agriculture and settlement expansions. Given these challenges, the future conservation and persistence of *Z. chalybeum* looks uncertain, which requires such measures as the provision of education and awareness and ensuring proper land-use plans that encompass active recruitment of the species in these areas.

Keywords: herbs; conservation; anthropogenic; land use; Maasai

1. Introduction

Traditional medicines are vital components of healthcare in Tanzania [1]. Although there has been an increase in the modern health care, more than 60% of Tanzania's population and mostly 80% of the rural people depend on traditional medicine as a source of their primary health care [2]. Ref. [3], have reported that 25% of the world's biodiversity of plant species is used for medicinal purposes. The reasons for the high dependency on traditional medicine, especially by rural people, are cultural conservatism, poverty, and shortage of reliable and affordable conservative healthcare services [4,5]. Moreover, traditional medicines are easily accessed by people with low income, but who are also well equipped with the therapeutic knowledge of individual plants and have limited access to modern healthcare services [6]. Despite the vast richness of medicinal plants in Tanzania, their therapeutic effectiveness, and high dependence of these plants by a large population, minimal research exists which hinders their promotion and conservation concerns within the country [1].

One of the vital and famous medicinal plants among the community of Northern Tanzania and Simanjiro is *Zanthoxylum chalybeum*, locally known as “Oloisuki” in Maasai. *Zanthoxylum chalybeum* (Rutaceae), or “Mkunungu” in Swahili, is a traditional medicinal plant of Eastern Africa, characterized by a rounded but open crown, deciduous spiny shrub or tree growing up to 12 m, and dark seeds when

matured, and it often grows on termite mounds [7]. *Zanthoxylum chalybeum* is an important medicinal plant for malaria treatment, fever, cough, headaches, chest pain, digestive disorders (e.g., ulcers), some problems associated with the female reproductive system, diabetes, and toothache [5,8–12]. Moreover, according to [12], the tree species is of economic importance to most of the rural communities who have inadequate livelihood resources. The plant leaves have been processed to make vegetables in powder form and sold in the market at TZS 2000 (USD 1.5) for 500 g and thus provide income. Other uses of the tree include firewood and making utensils, including spoons and combs, charcoal, and carvings [12]. *Zanthoxylum chalybeum* has been reported in many studies as a significant medicinal plant sold in herbal markets [2,12–15].

Moreover, *Z. chalybeum* is harvested for export to Europe and the United States of America. One of the principal reasons for export is for making herbal tea as it thickens the tea and improves its flavor, while at the same time preventing diseases [10]. The species is thus subject to massive exploitation throughout its range areas, and the rates of natural recruitment in most areas where it occurs are considered to be low, with other original areas of its occurrence having lost the species [5].

The most effective plant fractions investigated and found to be most efficient in treating diseases are those of the root and stem bark, making the species more threatened to (local) extinction by how harvesting and utilization are done by members of the community. The effects of uprooting and bark-stripping on plants include wilting, stagnant growth, and sometimes cause plant death. Debarking of the plant stem has adverse effects on the plant such as blocking the translocation of materials, which is necessary for healthy growth and survival of the plant, increased risk of insect attack, and limited survival rate of the plant [16]. According to [2,5], *Z. chalybeum* is at the risk of extinction due to excessive exploitation, and thus immediate conservation efforts are needed. In Simanjiro areas, large quantities of *Z. chalybeum* are being exploited from the wild, raising concerns to whether these harvesting methods are sustainable. The problem facing the conservation of medicinal species is not only associated with overexploitation but also the manner in which the species are harvested. Harvesting is mainly through digging and cutting of roots, as well as bark removal. Moreover, there are increasing threats from the increased human population pressures and climate change effects which potentially hinder the survival and persistence of *Z. chalybeum*. This study, therefore, focused on assessing the challenges associated with the use and conservation of the *Z. chalybeum* tree by using a semi-structured questionnaire, and field observations in Simanjiro Area as a way of generating the information that can assist in developing future management actions and strategies for conservation. The study aimed to answer the following research questions; (i) What are the uses of *Z. chalybeum* by the community?, (ii) What is the preference of *Z. chalybeum* to the community?, (iii) What is the trend of *Z. chalybeum* availability?, (iv) Are the harvesting methods used by community members sustainable?, (v) What are the challenges for *Z. chalybeum* conservation?, and (vi) What conservation measures to be taken to ensure *Z. chalybeum* sustainability?

2. Materials and Methods

2.1. Description of the Study Area

Simanjiro is one of the districts in Manyara Region in Northern Tanzania. The district lies between 3°52' and 4°24' South and 36°05' and 36°39' East [17]. Simanjiro has an annual rainfall of 650 mm per annum and the mean monthly minimum and maximum temperatures of 18 and 30 °C, respectively. About 19,928.1 km² of the district and most of its area are covered by open woodland, grassland vegetation, and thick forests [17]. Moreover, 20,591 km² of the area lies within the Maasai steppe, of which 600 km² of the entire steppe is fertile land used for agriculture, while open areas cover 12,682 km², Game Controlled Areas, and hilly areas [17]. Increasing human population and climate change mean that the previous relatively intact savanna is subject to massive disturbances and exploitations (for local and commercial use) around Simanjiro Area, thus calling for the need for this assessment.

2.2. Sampling Design and Data Collection

Purposive sampling (non-probability sampling) was used to capture respondents' information on uses and conservation challenges associated with the *Z. chalybeum* tree from five selected villages (Terrat, Loiborsoit A, Londrekess, Naberera, and Namalulu). This method of sampling is used to focus on particular characteristics of a population that are of interest, which will best enable to answer the research questions. To study plant availability, traditional uses, and sustainability during plant harvesting, and conservation challenges and future conservation strategies of the local communities, open-ended, semi-structured questionnaires were administered to selected local participants from the selected villages, as well as engagement in focused group discussion (FGD). The interviews were built on the trust to conserve the knowledge of medicinal plant utilization and to improve the healthcare situation not only in Simanjiro Area but also in other parts of the country. The study was conducted from July 2019 to January 2020.

Respondents were asked to identify the possible therapeutic uses of the *Z. chalybeum* plant, the plant part harvested and method of use, the preference of use, rate of availability (whether increasing or decreasing), sustainability during harvesting, conservation challenges, and conservation measures that can be adopted to ensure *Z. chalybeum* plant sustainability. Key-informant interviews were administered to the elders (above 60 years old), district forest officer, and Non-Governmental Organizations (NGO's) that deals with conservation. The rate of preference for the *Z. chalybeum* plant for medicinal uses compared with other medicinal plants as a source of local remedy to the community was also explored. Sampling was done in such a way that sampling fraction was at least 5% of the population of individuals who had knowledge about the tree, were willing to share the information collected in this study, and had been residents of the study area for more than 10 years [18]. A total of 110 individual respondents (103 respondents from the local interview and seven key informants) were used in this study. A ground survey was also conducted to visualize the anthropogenic activities facing *Z. chalybeum*. The ground survey involved study on the extent of anthropogenic threats by observing signs of disturbance such as those of root digging, debarking, fire, and whole tree cut. It also involved study on *Z. chalybeum* distribution in different land uses types and lastly reviewing practices of *Z. chalybeum* cultivation among locals in Simanjiro area. The information obtained from the questionnaires was combined to document the real situation of and to provide recommendations for the utilization, threats, and conservation strategies of *Z. chalybeum* for the local communities in Simanjiro area.

2.3. Data Analysis

The collected data through semi-structured questionnaires were entered and coded into Microsoft Excel (version 2013). The data were cleaned to facilitate analysis. Statistical Package for the Social Sciences (SPSS) computer program version 21.0 was used to analyze the data [18]. Chi-square test was used to test for any significant relationships between plant part harvested and the disease cured. Microsoft Excel was used for graphical representations. Descriptive statistics were computed and defined to form a discussion.

3. Results

3.1. Respondent Characteristics

A total of 103 respondents, 54.4% females and 45.6% males, were engaged in this study. The majority of respondents were between the ages of 31 and 60 years old (61.2%), while the rest were between 18 and 30 years old (23.3%), and above 60 (15.5%). The study revealed that most of the respondents had the primary-education level (53.4%), secondary level (14.6%), and adult education (6.8%), while (25.2%) did not attend school. 44.7% of respondents were engaged in pastoralism as their occupation, while 30.1% were housewives and 17% were engaged in small businesses (Figure 1).

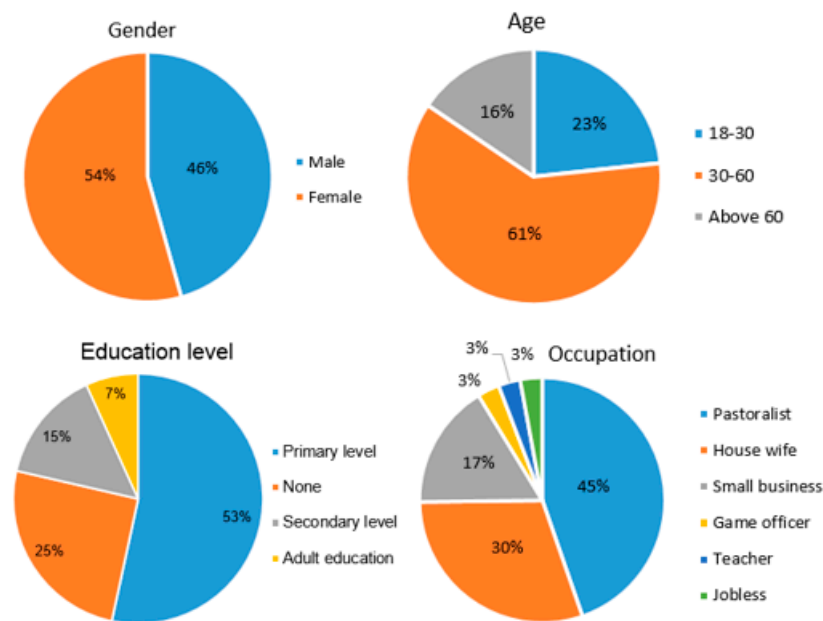


Figure 1. Socio-demographic characteristics of respondents in the study area.

3.2. Information on the Uses of the Plant and Harvesting Methods

The most frequent diseases mentioned by respondents to be cured with the *Z. chalybeum* tree were: women's health system (e.g., blood loss after labor, menstrual pain, early pregnancy complications) (86.4%), body aches (68%), fever (53.4%), chest pain (48%), and pneumonia (62.1%). Other mentioned diseases included abdominal pain (9%), general body immunity against diseases (19%), dizziness (15%), and malaria (10%) (Figure 2). According to the respondents, the plant was mostly used by all groups of people, but women were mostly using the plant after delivery to stop blood loss and reduce labor pain (76.7%). There was a strong relationship between plant part harvested and the disease cured ($\chi^2 = 408.8$, $df = 24$, $p = 1.16 \times 10^{-7}$).

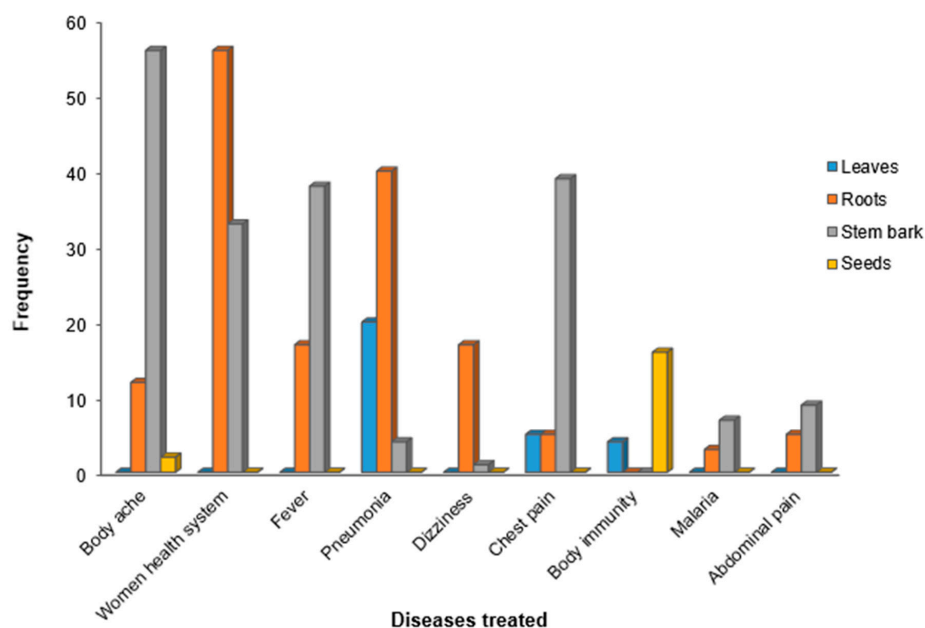


Figure 2. Reported diseases that can be treated with *Z. chalybeum*. The chart shows the frequency of responding individuals that use the plant for the treatment of a specific disease and the plant part used.

Ninety percent (90.3%) of respondents' preferred using *Z. chalybeum* to other medicinal plants available in their area because of its efficacy in treating diseases. Respondents also mentioned other uses of the *Z. chalybeum* plant to be as beverage (porridge and tea) spice (83.5%), ruminant fodder (especially seeds) (58%), for Boma fencing (30%), and as firewood (11.6%). Respondents mentioned root digging (93.2%), bark stripping (84.5%), seed harvesting (67%), and leaf pruning (56.3%) as the main methods used for harvesting. Wilting, plant death, stunting, and exposure to insect damage were the effects mentioned by respondents (85.4%, 20.4%, 15.5%, and 31.1%, respectively) resulting from excessive and unsustainable harvesting methods practiced (Figure 3).

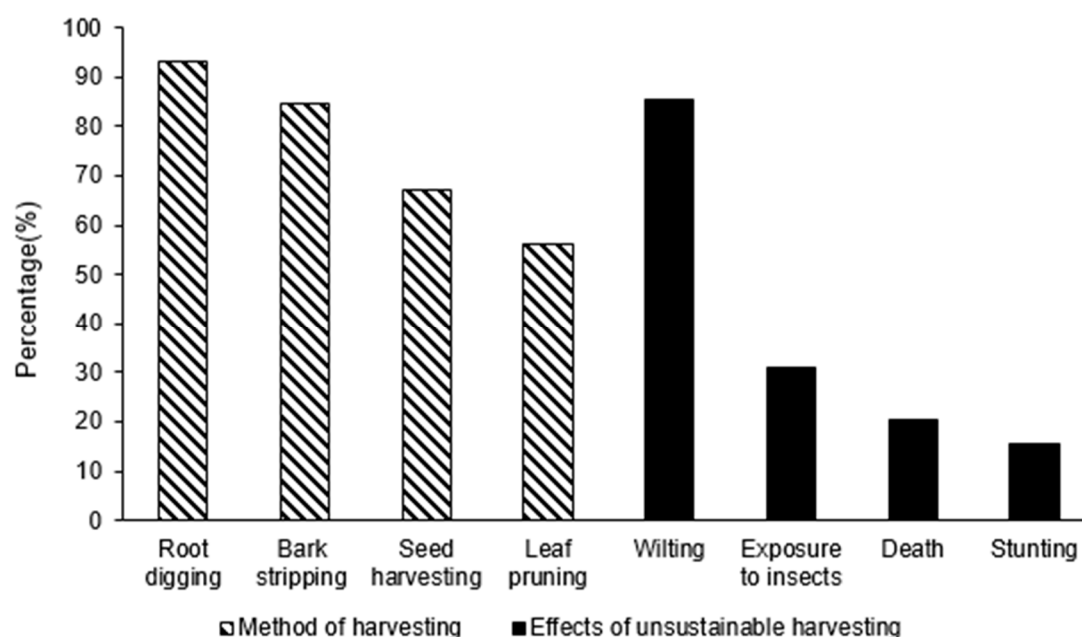


Figure 3. The percentage of respondents for the means they use for harvesting the medicinal plant *Z. chalybeum* and the effects resulting from unsustainable harvesting practices.

The majority of respondents mentioned roots and stem bark as the most used plant parts (90.3% and 81.6%, respectively) for remedy preparations, while seeds and leaves were used the least (58.2% and 31.1%, respectively). Boiling was reported as the primary method for medicine preparation, while drying and eating raw were the least mentioned methods (Table 1). The reasons given by the respondents on the preference for roots and bark over the other parts were long-term belief/knowledge (59%), more curative (more substantial medicinal effects) (77%), and the full-term availability of the plant parts (64%).

Table 1. Diseases treated, harvesting method, and mode of preparation of the *Z. chalybeum* tree as a medicine.

Disease Treated	Plant Part Harvested	Method of Use/Preparation
Fever	Roots	Wash, boil/soak in water, and drink
Women health system	Roots and stem bark	Wash, boil together, and drink the juice while hot
Dizziness	Roots	Wash, boil, and drink
Body ache	Stem bark	Boil and drink
Malaria Pneumonia	Stem bark Roots	Boil and drink Boil and drink while hot
Chest pain	Leaves and stem bark	Chew the raw leaves, boil the barks, and drink the juice
Abdominal pain	Roots	Boil/soak in water, make juice, and drink
Body immunity	Flowers and seeds	Dry the ingredients, grind, and mix into other beverages, use daily.

3.3. Information Gathered on Preference between Traditional Medical Care and Modern Medical Care Systems

Eighty-nine percent (89%) of respondents preferred traditional medicine over modern medicine (11%). According to the respondents, the preference for use of traditional medicine was due to traditional medicines being cheaper than modern medicines (89.3%) and safer (83.4%), inaccessibility of adequate modern care systems (76.6%), conserving their tradition (50.4%), easy accessibility (71.8%), and presence of diverse medicinal plants (29.1%) (e.g., Olkitalaswa (*Myrica salicifolia*), Orbukoi (*Terminalia brownii*), Osokonoi (*Warburgia ugandensis*), Olkiloriti (*Acacia nilotica*), Ormukutan (*Albizia anthelmintica*), and Olgumi (*Vangueria apiculata*), among which Oloisuki (*Zathoxylum chalybeum*) was most favoured) (Figure 4).

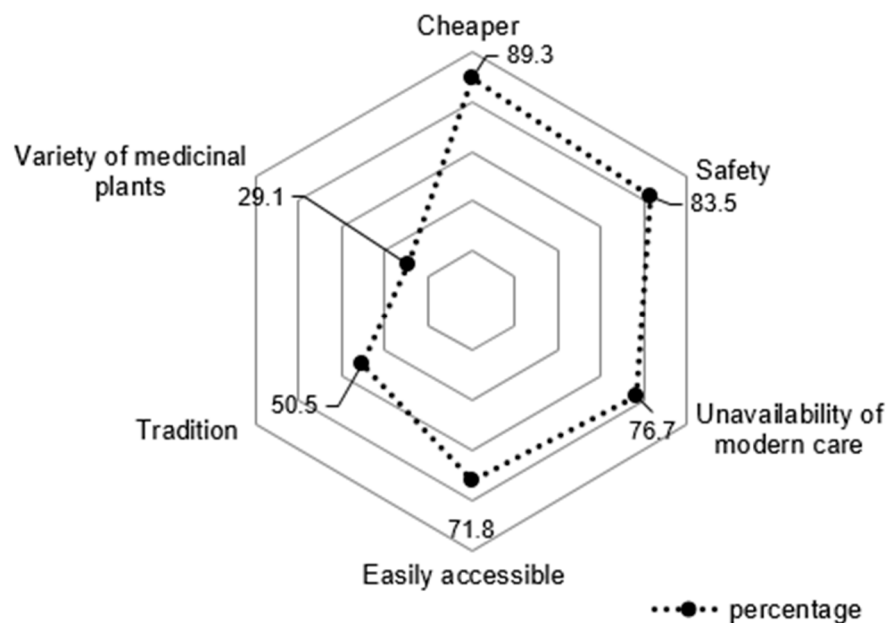


Figure 4. Radar chart showing reasons for the preference for traditional medicine treatment over modern healthcare services.

3.4. Information on the Availability of Medicinal Plant *Z. chalybeum* to the Community

Fifty-four percent (54.2%) of respondents claimed the plant was moderately available compared with the past 10 years, while 31.8% and 14.02% mentioned the same and very difficult availability, respectively. Most of the respondents pointed to forest (79.6%) and grazing lands (64%) as the main areas where they collected the plant, while few of the respondents mentioned owned farms (18.4%) and homesteads (14.5%) as the main areas. Furthermore, 76.7% of respondents agreed that there were places the plant was available in past years but not anymore which was caused by the change in land use to agriculture (93.2%), overexploitation (77.6%), unsustainable harvesting methods (64.07%), and increase in demand (68.9%) (Figure 5). According to the key-informant discussion, the trend of use and availability of this important medicinal plant is decreasing, the reasons for it being increased promotion of modern health care and hospitals (85.7%) and the decrease in the availability of medicinal plants (57.1%) as compared to the past 10 years.

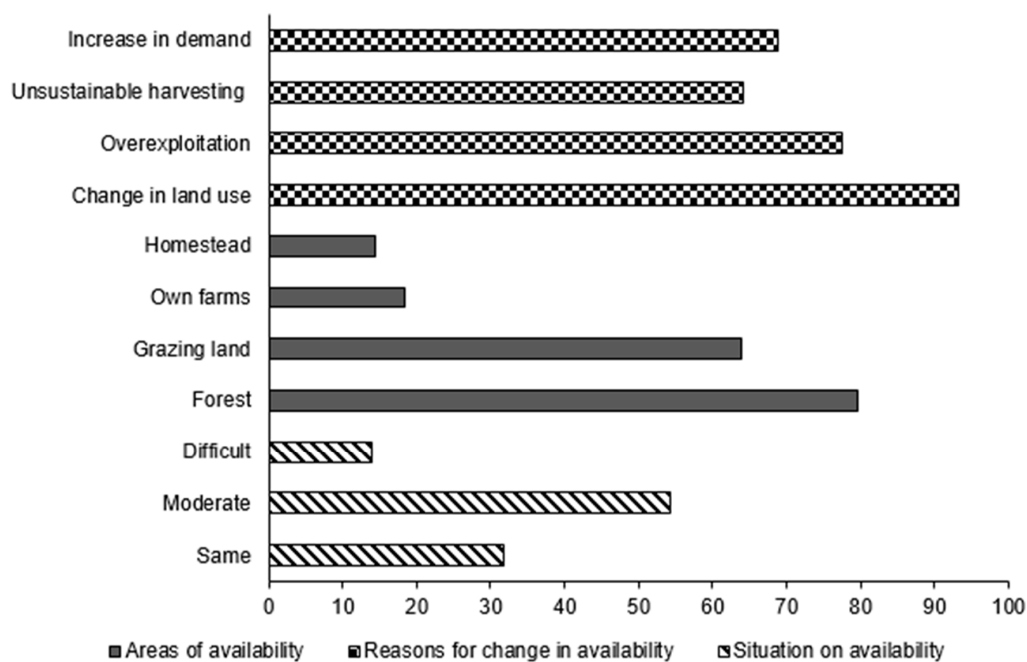


Figure 5. Represents the percentage (%) of respondents' view of the situation of plant availability, reasons for the change in availability, and areas where they find the plant for harvesting.

3.5. Information on Challenges and Conservation Measures Revealed by Respondents

In this study, we also gathered information on people's insights on conservation through domestication. Among respondents, 54.4% agreed on domestication/cultivation, while 45.6% disagreed, with the reasons for it being germination challenges (52.4%), lack of land (5.4%), lack of knowledge on tree propagation (17.5%), and lack of interest (26.2%). According to the data gathered from the key-informant discussion, conservation of medicinal plants in the area faces many challenges such as the change in land use to agriculture (99.9%), wildfires and charcoal burning (71.4%), weak government support for conservation (42.8%), unsuitable harvesting methods (71.4%), weak generation of medicinal plants (57.1%), and lack of conservation awareness among locals (85.7%) (Figure 6).

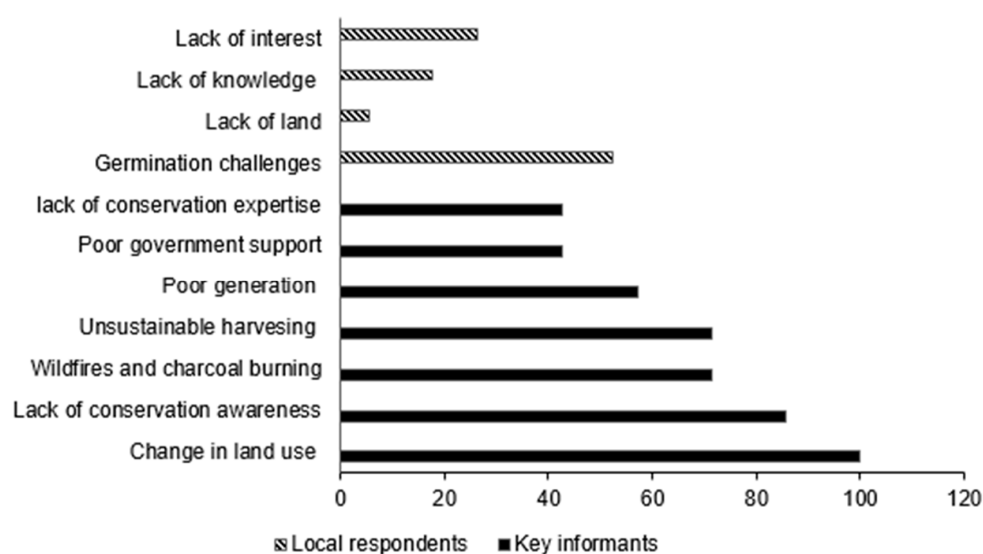


Figure 6. Challenges facing the conservation of the medicinal plant *Z. chalybeum* in Simanjoro Area as pointed out by local respondents and key informants.

According to the respondents, the conservation of the *Z. chalybeum* medicinal plants is important because medicinal plants provide employment for Maasai as herbalists (57.1%), it conserves the culture of Maasai (43%), it is a source of all other modern medicines (43%), and it contributes to the conservation of other natural resources (28.5%). Seeds (22.3%), seedlings (35.9%), and roots (15.5%) were mentioned by a few as a means of propagation that can be adopted. However, seeds show poor germination results, seedlings are challenging to find, and roots show no promising results to many. In order to conserve medicinal plants, different methods were suggested by the respondents such as providing education and awareness about conservation to the locals (98.1%), reducing excessive harvesting (87.4%); meanwhile, the suggestions from the key informants were: the government should set rules and regulations for the conservation of medicinal plants (57.1%), ensure proper land use and land-use planning (71.4%) and domestication (71.4%) (Figure 7).

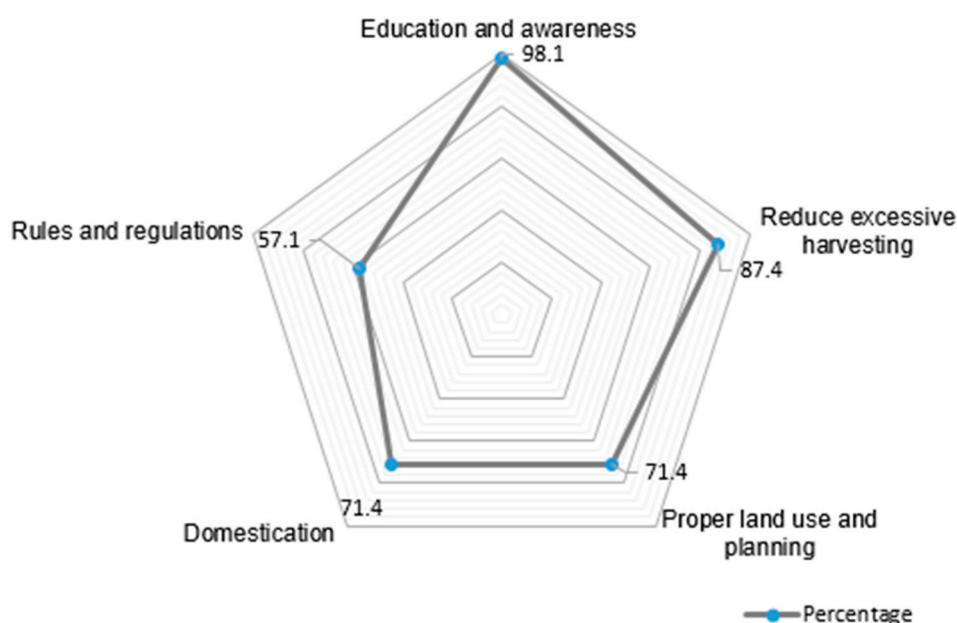


Figure 7. Radar chart showing conservation measures for the medicinal plant *Z. chalybeum* as suggested by the local community members and key informants.

3.6. Information on Field Survey Observations

A total of 134 trees were observed during field inventory, of which 63 trees were showing signs of anthropogenic disturbance such as root digging and bark stripping (16%), bark stripping (51%), debarking and branch cut (20%), whole tree cut (5%), and debarking, branch cut and uprooting (8%). The majority of the trees (77.6%) were observed in the wild (grazing lands, Game Controlled Areas and open areas), while 22.4% were observed in own farms and homesteads. Within 134 of the observed trees, only one tree was observed to contain a sapling, indicating a germination challenge for the plant.

4. Discussion

4.1. Characteristics of Respondents and Linking to the Dependence on Medicinal Plants

From the results above, it shows that the majority of respondents had the primary level of education, while some did not attend school at all (Figure 1). This situation influences their high dependence on natural resources and therefore jeopardizes the *Z. chalybeum* conservation efforts. According to [19], environmentally educated people know about ecology construction, the values influencing it, and can contribute to the application of ecological conservation. Furthermore, reports showed that the level of education of an individual tends to impact the rate of adoption of new conservation and management techniques of natural resources, including medicinal plants [20]. Low

level of education also hinders the chances of formal employment and thus forces people to depend on natural resources to employ themselves (either as herbalists or charcoal sellers), both of which limit conservation. Indicating this, we therefore encourage community members to be provided with education on environmental conservation starting with the lowest levels of education. The government should also work on educating the community through frequent conservation seminars and through local leaders. This approach will eventually bring positive results and reduce the risk of local extinction of the plant species.

4.2. Uses and Harvesting of the Medicinal Plant *Z. chalybeum*

The results showed that the plant is used to treat women's health systems (e.g., blood loss after labor, menstrual pain, and early pregnancy complications), body ache, fever, pneumonia, dizziness, chest pain, body immunity, malaria, and abdominal pain, which were similar to [5,9,10,12] reports. The primary means of drug preparation included decoction and oral admission. Many ethnobotanists use the decoction method because it is effective in extracting the chemical materials present in the plant part [21]. Furthermore, the roots and bark are the most used parts of the plant for medicinal remedies because of the belief in its effectiveness in curing diseases, which can be linked to [6] who reported that the "plant's roots and barks contain more concentrates of active compounds than other plant parts." However, higher utilization of roots and barks for medicine could harm the sustainability of medicinal plants, unless proper harvesting is implemented. According to [22–24], selecting permanent plant parts such as roots, bark, tubers, and reproductive parts for use as the source of medicines can threaten plant populations or species sustainability (by causing death, stagnant growth, wilting, and species extinction), thus sustainable harvesting should be well-thought-out. This implies that *Z. chalybeum* is under the threat of unsustainability since roots and barks are the main plant parts harvested. Thus, alternative tree planting around the homestead, incorporation of the tree into agroforestry and agro-agriculture practice, education, and awareness creation are conservation suggestions that will help reduce the pressure of harvesting to ensure plant stability.

4.3. Preference between Traditional Medicine and Modern Health Care

The majority of respondents preferred traditional medicines over modern medicines (Figure 4), the reasons being: traditional medicines are cheaper, safer, more accessible, and of larger diversity than modern medicines; unavailability of adequate modern care systems; and conservation of their traditions. Similar observations were reported by [1,6,25]. Most of Tanzania's rural residences have low income and face challenges with advanced technology in transportation, water availability, electricity, and modern health systems. This was observed in the study area during field survey, where the availability of hospitals and means of transportation were limited. As the population increases, the pressure on dependency on herbal medicine for rural people increases as well, meaning that increasing harvesting pressure will in the future lead to the *Z. chalybeum* species extinction as many of the plants are harvested in the wild. Therefore, we suggest improving social services and encouraging conservation of the medicinal plant since it is the health source of many people living in rural areas.

4.4. Availability of the Medicinal Plant *Z. chalybeum* to the Community

Based on the results (Figure 5), the primary sources of medicinal plants are wild areas such as forests and grazing lands, which is similar to the reports of [1,25,26]. The dependency on medicinal plants coming from the wild has, in turn, resulted in the disappearance of many sources as most of the plants are harvested unsustainably, and no records are made [1]. However, few families have engaged in domestication by planting *Z. chalybeum* in their home surroundings for quick accessibility, thus implying an awareness of conservation [1]. Therefore, we emphasize the need for more training and education to all medicinal plant users on domestication possibilities and sustainable ways of harvesting medicinal plants either by reducing excess harvest or by harvesting other plant parts (e.g., seeds and leaves) that can play a curing role but with minimum effect to the plant's survival.

4.5. Challenges and Conservation Measures for the Medicinal Plant *Z. chalybeum* in the Area

Several significant conservation challenges mentioned were noticeable due to change in land use to agriculture, overexploitation, unsustainable harvesting methods, and increase in demand for medicinal plants, as reported by [1,2,5], and others, including wildfires and charcoal burning, weak government support in encouraging conservation, unsuitable harvesting methods, inadequate generation of medicinal plants, and lack of conservation awareness among locals. Many conservationists have suggested conservation through domestication. However, the responses were low, the reasons for which being germination challenges, lack of land, lack of knowledge on tree propagation, and lack of interest [27], which are similar to the details gathered from the interviews in the study area. Moreover, propagation by using seeds in many cases showed challenges in germination, as reported by [28], the reasons for which being hard seed coat and the low germination rate. Similar reasons were pointed out by the respondents in Simanjiro District. These may slow down the domestication conservation campaigns; thus, more efforts for conservation in the wild should be heavily promoted, while research on enhancing seed germination is encouraged. According to the results above, conservation measures such as the provision of education and awareness, reducing excessive harvesting, the government setting rules and regulations for the conservation of medicinal plants, and ensuring proper land use and land-use planning and domestication aligned with [2,29,30] reports. Therefore, immediate conservation implications must be taken to ensure the continuation of the *Z. chalybeum* plant availability.

5. Conclusions

Medicinal plants are a source of employment for Maasai herbalists; they conserve the Maasai culture; they are a source of modern medicines; and they help conserve other natural resources (Section 3.5). It was observed, during the field inventory, that a few Simanjiro residents had started domesticating *Z. chalybeum*, and partial care during harvesting of medicinal plants was being taken. However, the conservation measures taken at the moment will not help in the long run as the demand for medicinal plants is growing, and most plant parts harvested are roots and stem barks. Even though respondents claim to be harvesting plant parts by making sure that they leave most of the tree behind so that it can survive, more efforts should be implemented to create conservation awareness among locals. If possible, the government should set regulations that will guide the use and exploitation of *Z. chalybeum*, especially as they are exploited in the wild. *Zanthoxylum chalybeum*, being a wild plant, is characterized by slow growth, space selectivity and human threat due to high demand. In combination, these are serious challenges to conservation; thus, we encourage allocation of areas for conservation to ensure availability of the plant. Furthermore, field observation revealed that many trees were having signs of anthropogenic disturbances (Section 3.6), mainly inside grazing areas that usually are not protected, implying that weak regulation of the use of natural resources and their utilization can hinder conservation efforts. Avoiding girdling, collection of few roots per plant, covering the soil after digging, and removing the bark from the opposite quarters of the trunks are measures to adopt for sustainable harvesting of *Z. chalybeum* for conservation. Furthermore, encouragement for *Z. chalybeum* domestication should be a priority in order to have a resource bank of *Z. chalybeum* instead of depending on resources in the wild. Finally, improvement of modern healthcare facilities can also reduce the pressure on harvesting and dependence on *Z. chalybeum* in the wild.

Author Contributions: Conceptualization, S.D.M. and L.K.M.; methodology, S.D.M.; software, S.D.M.; validation, L.K.M., I.B.N., and P.A.N.; formal analysis, S.D.M.; investigation, S.D.M.; resources, S.D.M.; data curation, S.D.M.; writing—original draft preparation, S.D.M.; writing—review and editing, L.K.M., P.A.N., and I.B.N.; visualization, S.D.M.; supervision, L.K.M., I.B.N., and P.A.N.; project administration, L.K.M. and P.A.N.; funding acquisition, S.D.M., L.K.M., and P.A.N. All authors have read and agreed to the published version of the manuscript.

Funding: The Centre for Research funded this research, Agricultural Advancement, Teaching Excellence and Sustainability in Food and Nutritional Security (CREATES).

Acknowledgments: We are very grateful to all those who have made this research work possible. Many thanks go to Julius Kimaro (Game Officer) from Tanzania Wildlife Management Authority (TAWA), Joseph Shamba and

Nyella from Simanjiro District (District Forest Officer), and Neovatus (Tanzania people and wildlife conservation NGO) for their assistance and for sharing information as key informants. To the Centre for Research, Agricultural Advancement, Teaching Excellence and Sustainability in Food and Nutritional Security (CREATES) for funding this research.

Conflicts of Interest: The authors declare no conflict of interest during submission of this manuscript.

References

1. Makule, E. Ethnopharmacological Survey and Phytochemical Investigation of Maasai Traditional Medicinal Plants from North-Eastern Tanzania. Ph.D. Thesis, University of Regensburg, Regensburg, Germany, 2018.
2. McMillen, H. Ethnobotanical knowledge transmission and evolution: The case of medicinal markets in Tanga, Tanzania. *Econ. Bot.* **2012**, *66*, 121–131. [\[CrossRef\]](#)
3. Mahunnah, R.L.A.; Mshigeni, K.E. Tanzania's policy on biodiversity prospecting and drug discovery programs. *J. Ethnopharmacol.* **1996**, *51*, 221–228. [\[CrossRef\]](#)
4. Swai, R.E.A. Utilization and Commercialization of Medicinal Tree Products in Tanzania. 2003. Available online: <https://new.worldagroforestry.org/publication/utilization-and-commercialization-medicinal-tree-products-tanzania> (accessed on 6 February 2020).
5. Nahashon, M. Conservation of Wild-harvested Medicinal Plant Species in Tanzania: Chain and Consequence of Commercial Trade on Medicinal Plant Species. Master's Thesis, Uppsala University, Uppsala, Sweden, 2013.
6. Kitula, R.A. Use of medicinal plants for human health in Udzungwa Mountains Forests: A case study of New Dabaga Ulongambi Forest Reserve, Tanzania. *J. Ethnobiol. Ethnomed.* **2007**, *3*, 7. [\[CrossRef\]](#)
7. June, M.; Kimani, C.N.; Mbaria, J.M.; Suleiman, M.; Gakuya, D.; Kiama, S.G. Antihyperglycemic activity of *Zanthoxylum chalybeum* stem bark extract in diabetic rats. *J. Phytoph.* **2015**, *4*, 183–189.
8. Moshi, M.J.; Mbwambo, Z.H. Experience of Tanzanian traditional healers in the management of non-insulin dependent diabetes mellitus. *Pharm. Biol.* **2002**, *40*, 552–560. [\[CrossRef\]](#)
9. Dharani, N.; Rukunga, G.; Yenesew, A.; Mbori, A.; Mwaura, L.; Dawson, I.; Jamnadass, R. Common antimalarial trees and shrubs of East Africa. In *A Description of Species and a Guide to Cultivation and Conservation through Use*; Dawson, I., Ed.; The World Agroforestry Centre (ICRAF): Nairobi, Kenya, 2010; pp. 73–76.
10. Laltaika, E. Oloisuki—A Tale of Bio Piracy in the Maasai Steppe, Tanzania. 2011, 9. Available online: https://www.academia.edu/14930270/Oloisuki_A_tale_of_biopiracy_in_the_Maasai_Steppe_Tanzania (accessed on 8 February 2020).
11. Bbosa, G.S.; Mwebaza, N.; Lubega, A.; Musisi, N.; Kyegombe, D.B.; Ntale, M. Antiplasmodial Activity of Leaf Extracts of *Zanthoxylum chalybeum*. *Engl. Br. J. Pharm. Res.* **2014**, *4*, 705. [\[CrossRef\]](#)
12. Balama, C.; Makatta, A.A.; Maduka, S.M.; Teweale, C. Nutrient content of dried leaves of *Zanthoxylum chalybeum* Engl. growing in semi-arid areas of Iringa region, Tanzania. *Tanzan. J. For. Nat. Conserv.* **2015**, *84*, 2.
13. Augustino, S.; Gillah, P.R. Medicinal plants in urban districts of Tanzania: Plants, gender roles and sustainable use. *Tanzan. J. For. Nat. Conserv.* **2005**, *7*, 44–58. [\[CrossRef\]](#)
14. Abihudi, S. Documentation and Identification of Medicinal Plants Traded in Tanzania by Means of DNA Barcoding. Ph.D. Thesis, Muhimbili University of Health and Allied Sciences, Dar es Salaam, Tanzania, 2014.
15. Posthouwer, C.; Veldman, S.; Abihudi, S.; Otieno, J.N.; van Andel, T.R.; de Boer, H.J. Quantitative market survey of non-woody plants sold at Kariakoo Market in Dar es Salaam, Tanzania. *J. Ethnopharmacol.* **2018**, *222*, 280–287. [\[CrossRef\]](#)
16. Delvaux, C.; Sinsin, B.; Darchambeau, F.; Van Damme, P. Recovery from bark harvesting of 12 medicinal tree species in Benin, West Africa. *J. Appl. Ecol.* **2009**, *46*, 703–712. [\[CrossRef\]](#)
17. Nyaruhucha, C.N.; Msuya, J.M.; Mamiro, P.S.; Kerengi, A.J. Nutritional status and feeding practices of under-five children in Simanjiro District, Tanzania. *Tanzan. J. Health Res.* **2006**, *8*. [\[CrossRef\]](#)
18. Mahonge, C.P.I.; Nsenga, J.V.; Mtengeti, E.J.; Mattee, A.Z. Utilization of medicinal plants by waluguru people in east Uluguru Mountains Tanzania. *Afr. J. Tradit. Complement. Altern. Med.* **2006**, *3*, 121–134. [\[CrossRef\]](#)
19. Ngondya, I.B.; Ibrahim, R.I.H.; Choo, G.C. Are poverty and illiteracy to blame for forests degradation? A case study of Mbeya range forest reserve. Mbeya-Tanzania. *J. For. Environ. Sci.* **2011**, *27*, 93–99.

20. Brewer, C. Translating data into meaning: Education in conservation biology. *Conserv. Biol.* **2006**, *20*, 689–691. [[CrossRef](#)]
21. Avwioro, G. Effectiveness of some medicinal plant decoction in the treatment of Malaria in Nigeria. *Ann. Biol. Res.* **2010**, *1*, 230–237.
22. Tabuti, J.R.; Lye, K.A.; Dhillon, S.S. Traditional herbal drugs of Bulamogi, Uganda: Plants, use and administration. *J. Ethnopharmacol.* **2003**, *88*, 19–44. [[CrossRef](#)]
23. Shrestha, P.M.; Dhillon, S.S. Medicinal plant diversity and use in the highlands of Dolakha district, Nepal. *J. Ethnopharmacol.* **2003**, *86*, 81–96. [[CrossRef](#)]
24. Cruse-Sanders, J.M.; Hamrick, J.L.; Ahumada, J.A. Consequences of harvesting for genetic diversity in American ginseng (*Panax quinquefolius* L.): A simulation study. *Biodivers. Conserv.* **2005**, *14*, 493–504. [[CrossRef](#)]
25. Augustino, S.; Hall, J.B.; Makonda, F.B.; Ishengoma, R.C. Medicinal plant parts and practices used by communities around the Miombo woodlands of Urumwa, Tanzania. *J. Med. Plant Res.* **2014**, *8*, 599–606.
26. Roulette, C.J.; Njau, E.F.A.; Quinlan, M.B.; Quinlan, R.J.; Call, D.R. Medicinal foods and beverages among Maasai agro-pastoralists in northern Tanzania. *J. Ethnopharmacol.* **2018**, *216*, 191–202. [[CrossRef](#)]
27. Tchoundjeu, Z.; Degrande, A.; Leakey, R.R.; Nimino, G.; Kemajou, E.; Asaah, E.; Tsobeng, A. Impacts of participatory tree domestication on farmer livelihoods in West and Central Africa. *For. Trees Livelihoods* **2010**, *19*, 217–234. [[CrossRef](#)]
28. Datt, G.; Chauhan, J.S.; Ballabha, R. Influence of pre-sowing treatments on seed germination of various accessions of Timroo (*Zanthoxylum armatum* DC.) in the Garhwal Himalaya. *J. Appl. Res. Med. Aromat. Plants* **2017**, *7*, 89–94. [[CrossRef](#)]
29. Mahunnah, R.L.A.; Augustino, S.; Otieno, J.N.; Elia, J. Conservation assessment and Management Planning of Medicinal Plants in Tanzania. *Med. Plant Conserv.* **2012**, *15*, 35–41.
30. Rajan, R.; Kumarasamy, M. Ethnomedicinal plant survey of Srivaikundam village of Tuticorin district, Tamilnadu, India. *Life Sci. Leaflet.* **2012**, *6*, 47–53.



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).